

TABLE 2
Ongoing SITE Demonstration Program Projects as of December 1996

Developer	Technology	Technology Contact	EPA Project Manager	Applicable Media	Applicable Waste	
					Inorganic	Organic
AlliedSignal Environmental Systems and Services, Inc., Des Plaines, IL (003)*	Biological Air Treatment System	Stephen Lupton 847-391-3224 800-462-4544 Andra Moffett 201-455-5894 800-626-4974	Ronald Lewis 513-569-7856	Air, Vapor Exhaust	Not Applicable	Biodegradable Organic Compounds, PAHs, Diesel Fuel, Chlorobenzene
Arctic Foundations Inc., Anchorage, AK (010A)	Cryogenic Barrier	Ed Yarmak 907-562-2741	Steven Rock 513-569-7149	Soil	Nonspecific Inorganics	Nonspecific Organics
CF Systems Corporation/ Morrison Knudsen,** Cleveland, OH (008)	Liquified Gas Solvent Extraction (LG-SX) Technology	Chris Shallice 216-523-6581 303-466-4489	Mark Meckes 513-569-7348	Soil, Sludge, Sediment, Wastewater	Not Applicable	VOCs, SVOCs, PAHs, PCBs, Dioxins, PCP
Colorado Department of Public Health and Environment (developed by Colorado School of Mines),*** Denver, CO (005)/(E01)	Constructed Wetlands-Based Treatment	James Lewis 303-692-3383	Edward Bates 513-569-7774	Acid Mine Drainage	Metals	Not Applicable
EET, Inc., Bellaire, TX (009)	TECHXTRACT® Process	Michael Bonem 713-662-0727	Dennis Timberlake 513-569-7547	Porous Solid Materials	Heavy Metals, Radionuclides	PCBs, Hydrocarbons
EG&G Environmental, Inc., Pittsburgh, PA (009)	NoVOCs™ In-Well Stripping Technology	James Beninati 412-920-5401	Michelle Simon 513-569-7469	Groundwater	Soluble Metals	BTEX, TCE, DCE, PAHs, Alcohols, Ketones
Electrokinetics, Inc.,*** Baton Rouge, LA (009)/(E03)	Electrokinetic Soil Processing	Elif Acar 504-753-8004	Randy Parker 513-569-7271	Soil, Sediment	Heavy Metals and Other Inorganics, Radionuclides	Nonspecific Organics
Geotech Development Corporation, Newark, NJ (009)	Cold-Top Ex Situ Vitrification of Chromium-Contaminated Soils	Thomas Tate 610-337-8515 William Librizzi 201-596-5846	Marta K. Richards 513-569-7692	Solids, Ash, Slag	Hexavalent Chromium, Heavy Metals	Not Applicable
Lasagna Public-Private Partnership, Cincinnati, OH (010A)	Lasagna In Situ Soil Remediation	Michael Roulier 513-569-7796 Sa Ho 314-694-5179	Ronald Turner or Michelle Simon 513-569-7775 or 513-569-7469	Groundwater, Soils	Nonspecific Inorganics	Nonspecific Organics

* Solicitation number

** An additional demonstration is planned for this technology. Refer to the profile in the Demonstration Program section (completed projects) for more information.

*** From Emerging Technology Program

TABLE 2 (Continued)
Ongoing SITE Demonstration Program Projects as of December 1996

Developer	Technology	Technology Contact	EPA Project Manager	Applicable Media	Applicable Waste	
					Inorganic	Organic
Lockheed Martin Missiles and Space Co. and Geokinetics International, Inc., Palo Alto, CA (009)	Electrokinetic Remediation Process	Steven Schwartzkopf 415-424-3176	Jack Hubbard 513-569-7507	Soil, Sludge, Sediment	Heavy Metals	Polar Organics
Matrix Photocatalytic Inc.,*** London, Ontario, Canada (009)/(E05)	Photocatalytic Air Treatment	Bob Henderson 519-660-8669	Richard Eilers 513-569-7809	Air	Not Applicable	VOCs, SVOCs
National Risk Management Research Laboratory, Cincinnati, OH (006)	Bioventing	Paul McCauley 513-569-7444	Jack Hubbard 513-569-7507	Soil	Not Applicable	Nonspecific Organics
Phytokinetics, Inc., North Logan, UT (010A)	Phytoremediation Process	Ari Ferro 801-750-0985 801-755-0891	Steven Rock 513-569-7149	Soil, Sediment, Groundwater	Not Applicable	Nonspecific Organics
Phytotech, Monmouth Junction, NJ (010A)	Phytoremediation Technology	Michael Blaylock or John Ehrler 908-438-0900	Steven Rock 513-569-7149	Soil, Groundwater, Sediment	Heavy Metals, Radionuclides	Not Applicable
Pintail Systems Incorporated, Aurora, CO (009)	Spent Ore Bioremediation Process	Leslie Thompson 303-367-8443	Jack Hubbard 513-569-7507	Spent Ore, Waste Rock, Mine Tailings, Mining Process Water	Cyanide	Not Applicable
Praxis Environmental Technologies, Inc., Burlingame, CA (008)	In Situ Thermal Extraction Process	Lloyd Stewart 415-548-9288 Captain Jeff Stinson 904-283-6254	Paul dePercin 513-569-7797	Soil, Groundwater	Not Applicable	VOCs and SVOCs, Hydrocarbons, Solvents
Process Technologies, Inc., Boise, ID (009)	Photolytic Destruction of Vapor-Phase Halogens	Mike Swan 208-385-0900 Phil Mook 916-643-5443	Paul dePercin 513-569-7797	Air, Gases	Not Applicable	VOCs, CFCs, HCFCs
Recycling Sciences International, Inc., Chicago, IL (009)	Desorption and Vapor Extraction System	William Meenan 312-663-4242	Richard Eilers 513-569-7809	Soil, Sediment, Sludge	Volatile Inorganics	VOCs, SVOCs, PCBs, PAHs, PCP, Pesticides
RKK, Ltd., Arlington, WA (009)	CRYOCELL®	Ronald Krieg 360-653-4844	Steven Rock 513-569-7149	Soil	Nonspecific Inorganics	Nonspecific Organics

*** From Emerging Technology Program

TABLE 2 (Continued)
Ongoing SITE Demonstration Program Projects as of December 1996

Developer	Technology	Technology Contact	EPA Project Manager	Applicable Media	Applicable Waste	
					Inorganic	Organic
Sandia National Laboratories, Albuquerque, NM (009)	In Situ Electrokinetic Extraction System	Eric Lindgren 505-844-3820 Earl Mattson 505-856-3311	Randy Parker 513-569-7271	Soil	Anionic Heavy Metals, Hexavalent Chromium	Not Applicable
Selentec Environmental Technologies, Inc., Atlanta, GA (010A)	Selentec MAG*SEP SM Technology	Steve Weldon 770-640-7059	Randy Parker 513-569-7271	Water, Wastewater	Heavy Metals, Radionuclides	Not Applicable
Sevenson Environmental Services, Inc., Munster, IN (009)	MAECTITE® Chemical Treatment Process	Karl Yost 219-836-0116	Jack Hubbard 513-569-7507	Soil, Sludge, Sediment, Solids	Lead, Other Heavy Metals	Not Applicable
SIVE Services, Dixon, CA (009)	Steam Injection and Vacuum Extraction	Douglas Dieter 916-678-8358	Michelle Simon 513-569-7469	Soil	Not Applicable	VOCs, SVOCs
SOLUCORP Industries, West Nyack, NY (009)	Molecular Bonding System®	Robert Kuhn 914-623-2333	Thomas Holdsworth 513-569-7675	Soil, Sludge, Sediment, Ash	Heavy Metals	Not Applicable
Terra Kleen Response Group, Inc.,** Del Mar, CA (010A)	Solvent Extraction Treatment System	Alan Cash 619-558-8762	Terrence Lyons 513-569-7589	Soil, Sludge, Sediment	Not Applicable	PCBs, PCP, PAH, Creosote, Chlorinated Pesticides, PCDD, PCDF
U.S. Air Force, Wright Patterson Air Force Base, OH (010A)	Phytoremediation of TCE-Contaminated Shallow Groundwater	Greg Harvey 513-255-7716, ext. 302	Steven Rock 513-569-7149	Groundwater, Soil	Not Applicable	TCE, Petroleum, Munitions Halogenated Hydrocarbons
Vortec Corporation,** Collegeville, PA (009)/(E04)	Oxidation and Vitrification Process	James Hnat 610-489-2255	Teri Richardson 513-569-7949	Soil, Sludge, Sediment	Metals, Other Nonspecific Inorganics	Nonspecific Organics
Western Research Institute,** Laramie, WY (005)/(E04)	Contained Recovery of Oily Wastes	Lyle Johnson 307-721-2281	Eugene Harris 513-569-7862	Soil, Groundwater	Not Applicable	Coal Tars, Petroleum By-Products, PCP, Chlorinated Solvents
Wheelabrator Technologies Inc., Hampton, NH (008)	WES-PHix® Stabilization Process	Mark Lyons 603-929-3403	Teri Richardson 513-569-7949	Municipal Waste Combustion Ash, Soil, Sludge	Lead, Cadmium, Copper, Zinc, other Heavy Metals	Not Applicable

** An additional demonstration is planned for this technology. Refer to the profile in the Demonstration Program section (completed projects) for more information.

*** From Emerging Technology Program

ALLIEDSIGNAL ENVIRONMENTAL SYSTEMS AND SERVICES, INC. (Biological Air Treatment System)

TECHNOLOGY DESCRIPTION:

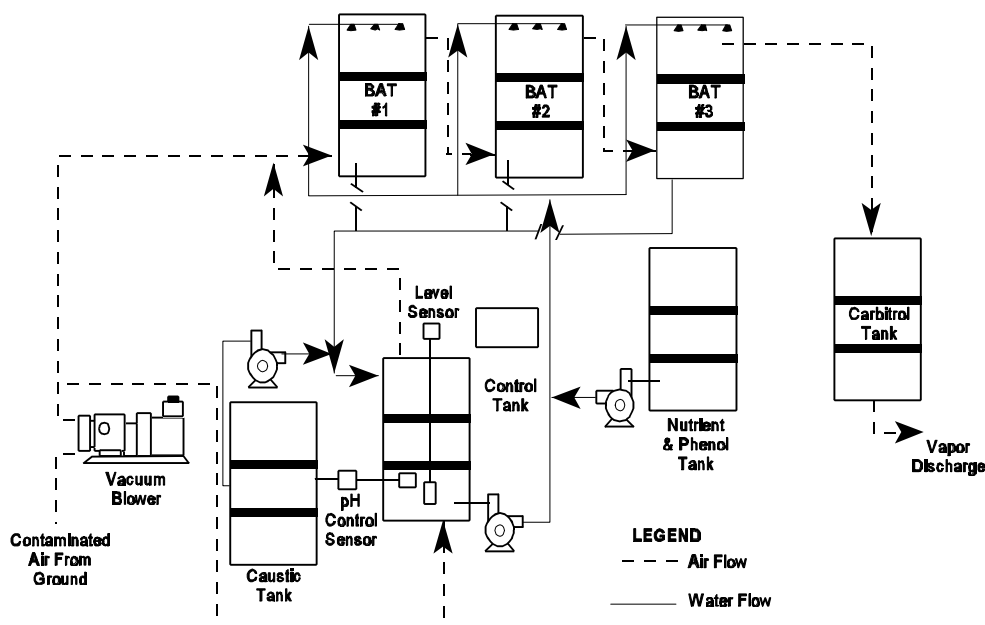
AlliedSignal Environmental Systems and Services, Inc. (AlliedSignal), has developed a biological air treatment (BAT) system that purifies contaminated air streams (see figure below). This system uses a biomass support matrix consisting of porous polyurethane foam with a surface area-to-volume ratio greater than 200 square feet per cubic foot. This support matrix is coated with powdered activated carbon (PAC) using a proprietary procedure that maintains the carbon in an activated state.

The carbon-coated foam support matrix is then mixed with polypropylene spacers, yielding a "mixed media" packing. The mixed media packing gives the support base rigidity and provides spaces between adjacent carbon-coated porous foam blocks. This open spacing gives the BAT system good distribution and mass transfer characteristics.

It also results in low back pressures at gas retention times as low as 30 to 60 seconds.

The BAT's unique support matrix has been used in conjunction with spacers such as HiFlow pall rings, which enable the BAT system to achieve removal rates greater than 92 percent for benzene, toluene, ethylbenzene, and xylene (BTEX). These removal rates have been achieved at loading rates up to 60 grams BTEX per cubic meter per hour while maintaining back pressures of less than 4 pounds per square inch at a linear minute space velocity of 0.5 minute.

Moisture content, nutrient levels, and pH are controlled by introducing a slow downward flow of water countercurrent to the air flow. The water then exits the reactor and enters a small holding reservoir where the pH of the water is monitored and automatically readjusted to pH 7. The water can then be recycled to the reactor. High initial organic



Biological Air Treatment System

loading rates result in considerable acid generation, and pH control is essential. Nitrogen (in the form of ammonia or nitrate) and phosphate nutrients are monitored and added to the reservoir to ensure that organic pollutants continue to biodegrade. The conductivity of the water in the reservoir is also monitored, and a portion of the water is periodically replaced to prevent buildup of dissolved salts.

WASTE APPLICABILITY:

The BAT system can be applied to any air or vapor exhaust system that contains biodegradable organic contaminants, including aromatic hydrocarbons such as BTEX and naphthalene, as well as biodegradable chlorinated organics such as trichloroethene (TCE). Several commercial BAT units are being used to treat exhaust gases from creosote wood preserving operations. These systems have reduced total volatile organic compound emissions by more than 90 percent and have dramatically reduced odor problems at these sites. Other applications include treatment of soil vapor extraction systems, commercial bakeries, pharmaceutical plants, food processing plants, and chemical plants.

STATUS:

This technology was accepted in the SITE Demonstration Program in 1995. The BAT system is being demonstrated at the AlliedSignal St. Joseph, Michigan Superfund site. Demonstration activities began in August 1995 and will continue through fall and winter 1996. The technology is being used in conjunction with a soil vapor extraction system to remove TCE and other chlorinated ethenes.

FOR FURTHER INFORMATION:

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ARCTIC FOUNDATIONS INC. (Cryogenic Barrier)

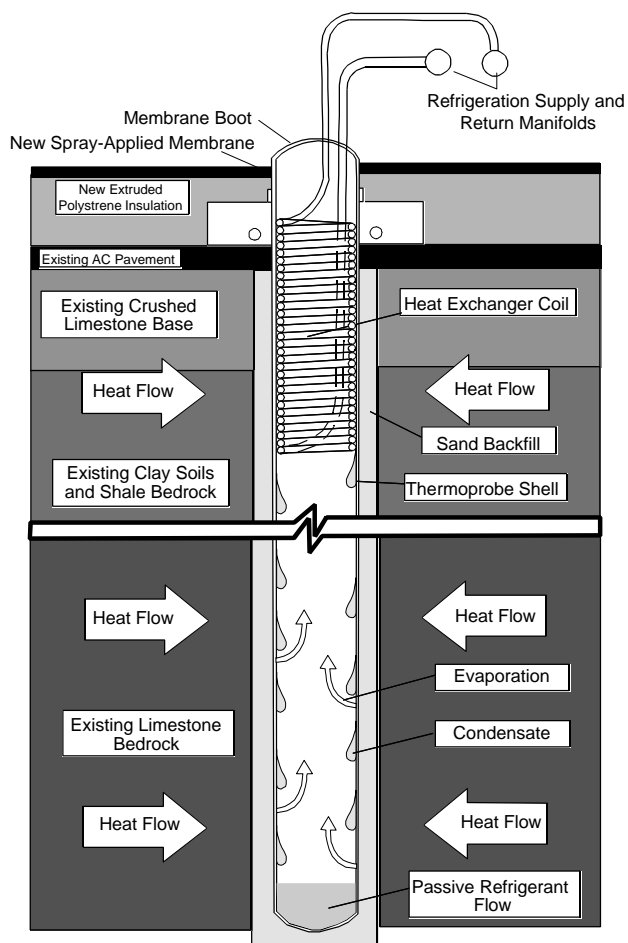
TECHNOLOGY DESCRIPTION:

Long-term containment and immobilization of hazardous wastes using ground-freezing technology is a relatively new field, even though ground-freezing has been used as a temporary construction aid for several years. Ground-freezing is ideally suited to control waterborne pollutants, since changing water from a liquid to a solid has an obvious immobilizing effect. The challenge for conventional ground-freezing technologies is to be technically and economically viable in the long-term. Arctic Foundations, Inc. (AFI), has developed a ground-freezing technology that has been used as a permanent, long-term solution for containing and immobilizing hazardous wastes.

Buried hazardous waste may be totally confined by

surrounding it with a frozen barrier. A frozen barrier is created by reducing the ground temperature around the waste to the correct freezing temperature and subsequently freezing the intervening waste. Artificial injection of water is usually unnecessary since moisture is present in sufficient quantities in most soils. The ground-freezing process is naturally suited to controlling hazardous waste because in-ground moisture is transformed from serving as a potential waste mobilizing agent to serving as a protective agent.

A typical containment system consists of multiple thermoprobe, and active (powered) condenser, an interconnecting piping system, two-phase working fluid, and a control system. The thermoprobes (AFI's heat removal devices) and piping are inserted



Cryogenic Barrier Insulation Plan

into the soil on all sides and underneath the waste. Two-phase working fluid circulates through the piping and reduces the temperature of the surrounding soil, creating a frozen barrier around the waste. The thermoprobes may be installed in any position and spacing to create a frozen barrier wall of almost any required shape and size. The selection of working fluids depends on the specific waste application, site conditions, and desired soil temperatures, and may consist of freon, butane, propane, carbon dioxide, or ammonia.

WASTE APPLICABILITY:

The cryogenic barrier can provide subsurface containment for a variety of sites and wastes, including the following: underground storage tanks; nuclear waste sites; plume control; burial trenches, pits, and ponds; in situ waste treatment areas; chemically contaminated sites; and spent fuel storage ponds. The barrier is adaptable to any geometry; drilling technology presents the only constraint.

STATUS:

The system was accepted in the SITE Demonstration Program in 1996. The demonstration will evaluate the barrier's ability to contain radionuclides from the Oak Ridge National Laboratory (ORNL) Waste Area Grouping 9 Homogeneous Reactor Experiment (HRE) pond. Hydrological data indicate that radioactive contaminants are being released from the HRE pond to the groundwater and surface water.

FOR FURTHER INFORMATION:

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TECHNOLOGY DEVELOPER CONTACT:

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**COLORADO DEPARTMENT OF PUBLIC
HEALTH AND ENVIRONMENT**
(developed by COLORADO SCHOOL OF MINES)
(Constructed Wetlands-Based Treatment)

TECHNOLOGY DESCRIPTION:

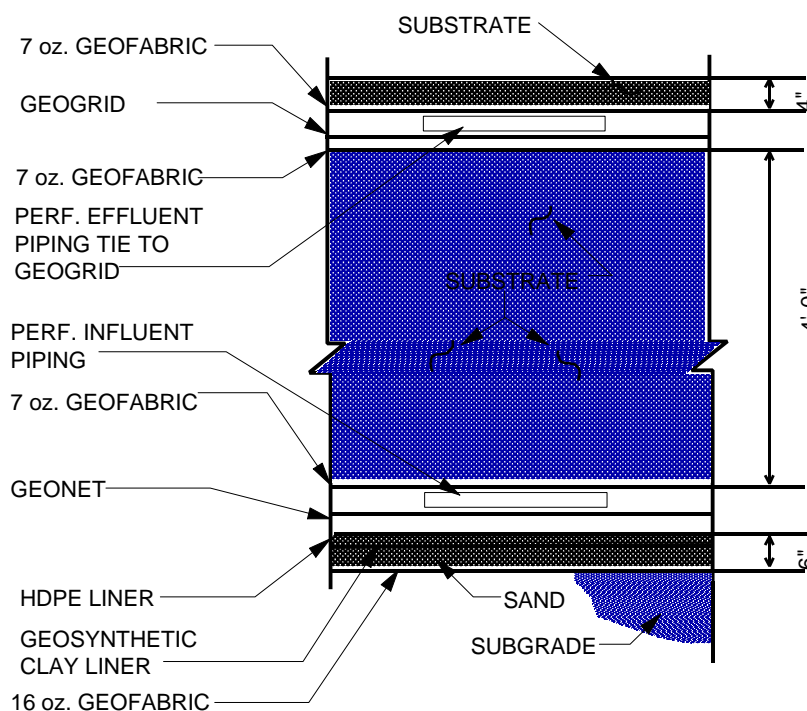
The constructed wetlands-based treatment technology uses natural geochemical and microbiological processes inherent in an artificial wetland ecosystem to accumulate and remove metals from influent waters. The treatment system incorporates principal ecosystem components found in wetlands, such as organic materials (substrate), microbial fauna, and algae.

Influent waters with high metal concentrations flow through the aerobic and anaerobic zones of the wetland ecosystem. Metals are removed by ion exchange, adsorption, absorption, and precipitation through geochemical and microbial oxidation and reduction. Ion exchange occurs as metals in the water contact humic or other organic

substances in the soil medium. Oxidation and reduction reactions that occur in the aerobic and anaerobic zones, respectively, precipitate metals as hydroxides and sulfides. Precipitated and adsorbed metals settle in quiescent ponds or are filtered out as the water percolates through the soil or substrate.

WASTE APPLICABILITY:

The constructed wetlands-based treatment process is suitable for acid mine drainage from metal or coal mining activities. These wastes typically contain high metals concentrations and low pH. Wetlands treatment has been applied with some success to wastewater in the eastern United States. The process may have to be adjusted to account for differences in geology, terrain,



Schematic Cross Section of Pilot-Scale Upflow Cell

trace metal composition, and climate in the metal mining regions of the western United States.

STATUS:

Based on the SITE Emerging Technology Program (ETP) results, the constructed wetlands-based treatment process was selected for the SITE Demonstration Program in 1991. For further information on the ETP evaluation, refer to the Emerging Technology Summary (EPA/540/SR-93/523), the Emerging Technology Report (EPA/540/R-93/523), or the Emerging Technology Bulletin (EPA/540/F-92/001), which are available from EPA.

Studies under the Demonstration Program are evaluating process effectiveness, toxicity reduction, and biogeochemical processes at the Burleigh Tunnel, near Silver Plume, Colorado. Treatment of mine discharge from the Burleigh Tunnel is part of the remedy for the Clear Creek/Central City Superfund site. Construction of a pilot-scale treatment system began in summer 1993 and was completed in November 1993.

The pilot-scale treatment system is about 4,200 square feet and consists of an upflow cell (see figure on previous page) and a downflow cell. Each cell treats about 7 gallons per minute of flow. Preliminary results indicate high removal efficiency (between 80 to 90 percent) for zinc, the primary contaminant in the discharge during summer operation. Zinc removal during the first winter of operation ranged from 60 to 80 percent. The demonstration is scheduled to run through the summer of 1997.

In 1994, removal efficiency of dissolved zinc for the upflow cell between March and September remained above 90 percent; however, the removal efficiency between September and December declined to 84 percent due to the reduction in microbial activity in the winter months. The downflow cell removal efficiency

dropped to 68 percent in the winter months and was between 70 and 80 percent during the summer months. The 1995 removal efficiency of dissolved zinc for the upflow cell declined from 84 percent to below 50 percent due to substrate hydrologic problems originating from attempts to insulate this unit during the winter months. The 1995 removal efficiency of the downflow cell declined from 80 percent during the summer months to 63 percent during the winter again as a result of reduced microbial activity. The 1996 removal efficiency of dissolved zinc calculated for the downflow cell increased from a January low of 63 percent to over 95 percent from May through August. The reason for the increase in the downflow removal efficiency is related to reduced flow rates through the downflow substrate which translates to increased residence time.

FOR FURTHER INFORMATION:

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EET, INC.
(TECHXTRACT® Process)

TECHNOLOGY DESCRIPTION:

The TECHXTRACT® process employs proprietary chemical formulations in successive steps to remove polychlorinated biphenyls (PCB), toxic hydrocarbons, heavy metals, and radionuclides from the subsurface of porous materials such as concrete, brick, steel, and wood. Each formulation consists of chemicals from up to 14 separate chemical groups, and each formulation can be specifically tailored to each contaminated site.

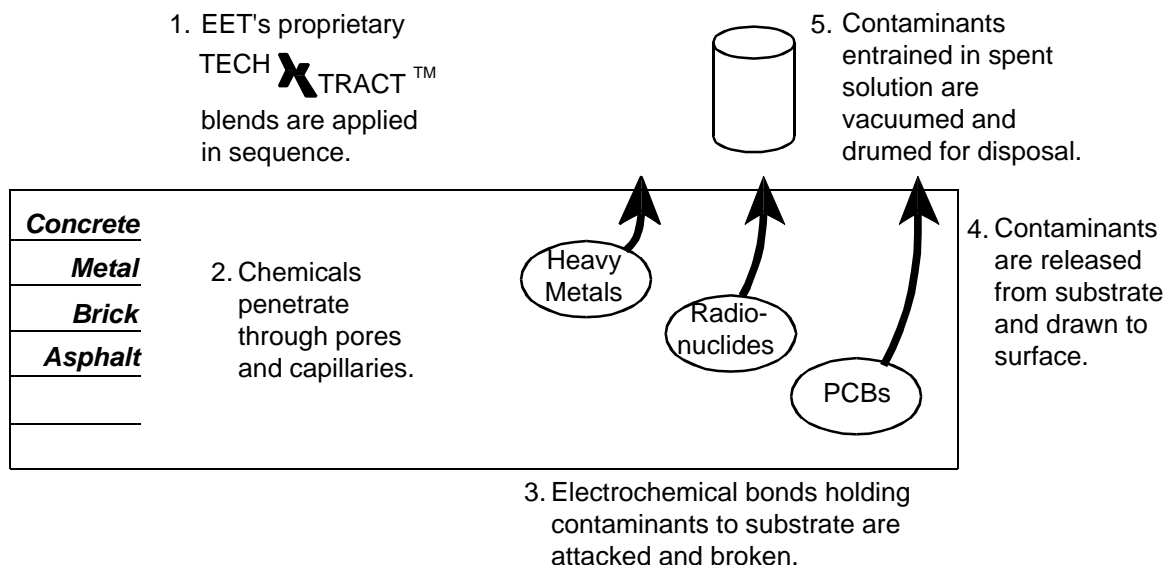
The process is performed in multiple cycles. Each cycle consists of three stages: surface preparation, extraction, and rinsing. Each stage employs a specific chemical mix.

The surface preparation step uses a solution that contains buffered organic and inorganic acids, sequestering agents, wetting agents, and special hydrotrope chemicals. The extraction formula

includes macro- and microemulsifiers in addition to electrolyte, flotation, wetting, and sequestering agents. The rinsing formula is pH-balanced and contains wetting and complexing agents. Emulsifiers in all the formulations help eliminate fugitive releases of volatile organic compounds or other vapors.

The chemical formulation in each stage is sprayed on the contaminated surface as a fine mist and worked into the surface with a stiff bristle brush or floor scrubber. The chemicals are allowed to penetrate into the subsurface and are then rinsed or vacuumed from the surface with a high-efficiency, particulate air-filtered, barrel-vacuum. No major capital equipment is required.

Contaminant levels can be reduced from 60 to 90 percent per cycle. One cycle can take up to 24 hours. The total number of cycles is determined from initial contaminant concentrations and final



Process Flow Diagram of the TECHXTRACT® Process

concentration target levels.

WASTE APPLICABILITY:

The TECHXTRACT® process is designed to treat porous solid materials contaminated with PCBs; toxic hydrocarbons; heavy metals, including lead and arsenic; and radionuclides. Because the contaminants are extracted from the surface, the materials can be left in place, reused, or recycled. After treatment, the contaminants are concentrated in a small volume of liquid waste.

In commercial applications, the process has reduced PCB concentrations from 1,000,000 micrograms per 100 square centimeters ($\mu\text{g}/100\text{ cm}^2$) to concentrations less than $0.2\text{ }\mu\text{g}/100\text{ cm}^2$. The TECHXTRACT® process has been used on concrete floors, walls and ceilings, tools and machine parts, internal piping, valves, and lead shielding. The TECHXTRACT® process has removed lead, arsenic, technetium, uranium, cesium, tritium, and thorium.

STATUS:

This technology was accepted into the SITE Demonstration Program in summer 1994. EET, Inc.'s (EET) demonstration is on hold pending site selection and notice to proceed by EPA.

The technology has been used in over 200 successful decontamination projects for the U.S. Department of Energy; U.S. Department of Defense; the electric, heavy manufacturing, steel, and aluminum industries; and other applications. Further research is underway to apply the technology to soil, gravel, and other loose material. EET also plans to study methods for removing or concentrating metals in the extracted liquids.

FOR FURTHER INFORMATION:

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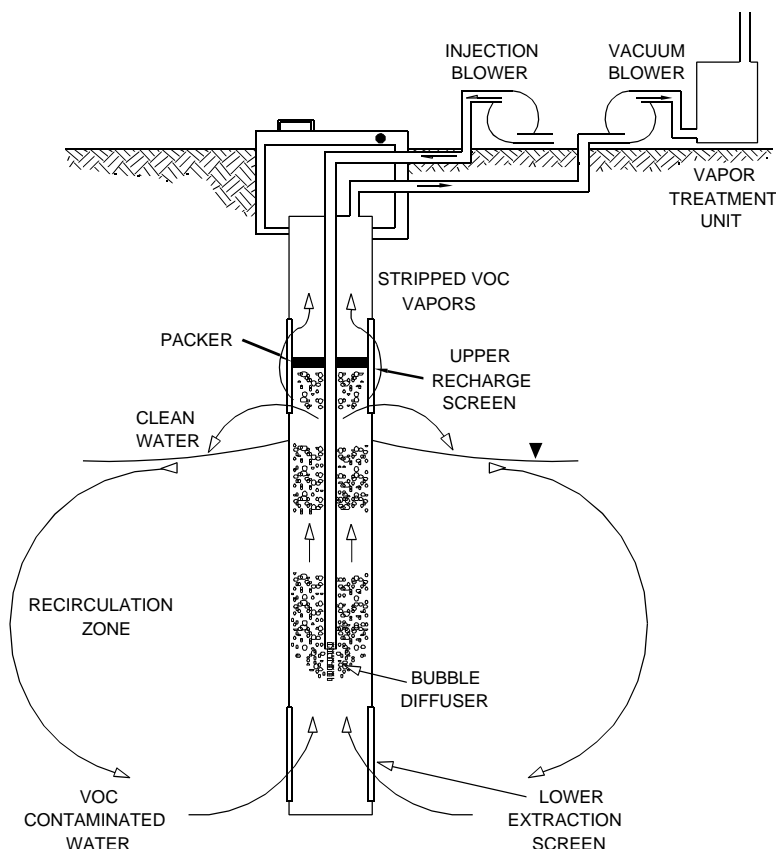
EG&G ENVIRONMENTAL, INC.
(NoVOCs™ In-Well Stripping Technology)**TECHNOLOGY DESCRIPTION:**

EG&G Environmental, Inc., has developed the patented NoVOCs™ in-well stripping technology for the in situ removal of volatile organic compounds (VOC) from groundwater (see figure below). NoVOCs™ combines air-lift pumping with in-well vapor stripping to remove VOCs from groundwater without the need to remove, treat, and discharge a wastewater stream. The process can also be adapted to remove both VOCs and soluble metals from groundwater.

NoVOCs™ consists of a well screened both beneath the water table and in the vadose zone. An air line within the well runs from an aboveground blower

and extends below the watertable. Pressurized air injected below the watertable aerates the water within the well, creating a density gradient between the aerated water and the more dense water in the surrounding aquifer. As a result, dense water flows in through the lower well screen and forces the aerated water upward within the well, while becoming aerated itself. The result is a rising column of aerated water within the well, or an air-lift pump.

As the aerated groundwater column rises within the well, VOC mass transfer occurs from the dissolved phase to the vapor phase. Above the water table, a packer is installed at the upper screen to prevent the passage of rising water or bubbles. The rising water



Schematic Diagram of the NoVOCs™ Technology

column hits the packer, the bubbles burst and the entrained VOC vapor is stripped off laterally through the screen by an upper vacuum casing. The VOC-rich vapor is brought to the surface for treatment while the laterally deflected water circulates back into the aquifer. Reinfiltrating water creates a toroidal circulation pattern around the well, enabling the groundwater to undergo multiple treatment cycles before flowing downgradient. The VOC-rich vapor is treated using commercially available techniques chosen according to the vapor stream characteristics.

NoVOCs™ can also be used to remove readily reduced metals from groundwater and stabilize them in the vadose zone. Solubilized metals in their oxidized states enter the lower screen by the same route as dissolved VOCs in the groundwater. The nonvolatile metals remain in solution as the VOCs are stripped at the upper screen and the water circulates out of the well. The groundwater and soluble metals then pass through an infiltration and treatment gallery surrounding the upper well screen. This treatment gallery is impregnated with a reducing agent which reduces the soluble metals to an insoluble valence state. The insoluble metals accumulate in the infiltration gallery high above the water table and can be either capped or excavated at the conclusion of remedial action.

WASTE APPLICABILITY:

The process treats groundwater contaminated by volatile petroleum hydrocarbons including benzene, ethylbenzene, and toluene, as well as chlorinated solvents such as tetrachloroethene and trichloroethene. Highly soluble organics like alcohols and ketones are not easily air-stripped from water but are readily biodegraded in the oxygen-rich environment produced by NoVOCs™.

STATUS:

The NoVOCs™ technology was accepted into the SITE Demonstration Program in 1995. The demonstration is scheduled to occur at Naval Air Station North Island in San Diego, California. The demonstration is on hold awaiting a Research Conservation and Recovery Act permit.

FOR FURTHER INFORMATION:

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ELECTROKINETICS, INC. (Electrokinetic Soil Processing)

TECHNOLOGY DESCRIPTION:

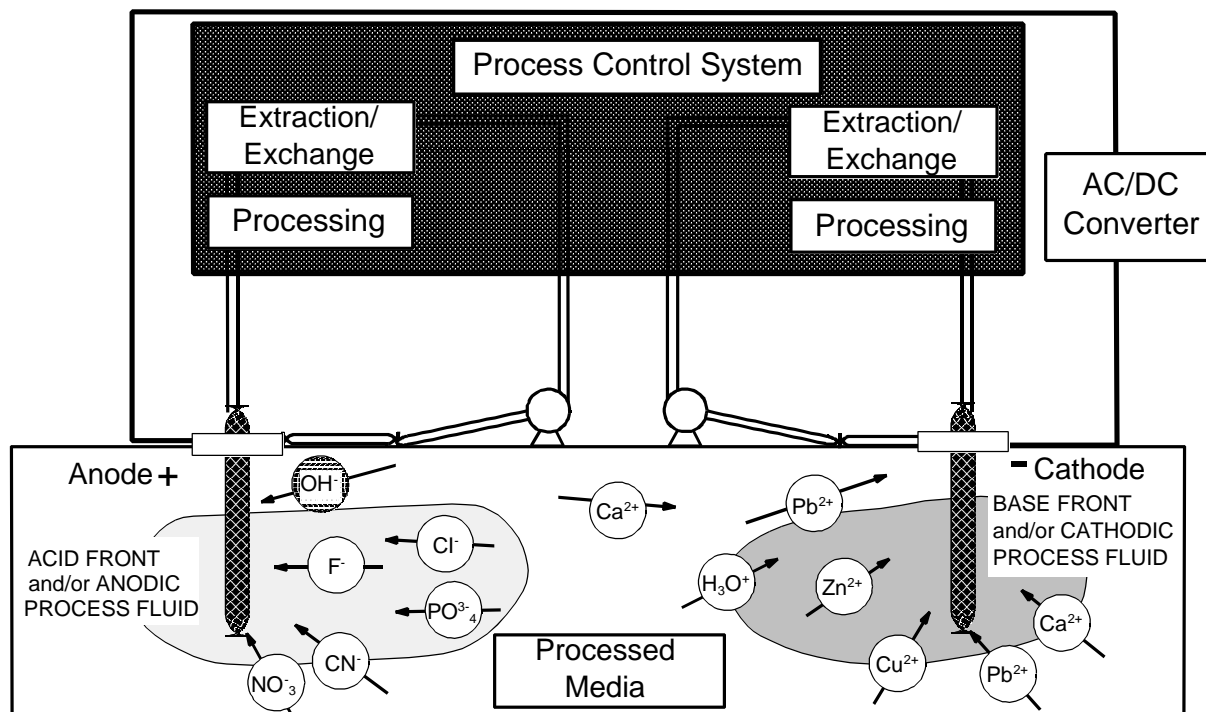
Electrokinetic, Inc.'s, soil processes extract or remediate heavy metals and organic contaminants in soils. The process can be applied in situ or ex situ with suitable chemical agents to optimize the remediation. For example, conditioning fluids such as suitable acids may be used for electrode (cathode) depolarization to enhance the process.

The figure below illustrates the field-processing scheme and the flow of ions to respective boreholes (or trenches). Electrodes are placed on each side of the contaminated soil mass, and a direct current is applied. Conditioning pore fluids may be added or circulated at the electrodes to control process electrochemistry.

Contaminants are electroplated on the electrodes or separated in a posttreatment unit.

An acid front migrates towards the negative electrode (cathode), and contaminants are extracted through electroosmosis (EO) and electromigration (EM). The concurrent mobility of the ions and pore fluid decontaminates the soil mass. EO and EM supplement or replace conventional pump-and-treat technologies.

Bench-scale results show that the process works in both unsaturated and saturated soils. Pore fluid flow moves from the positive electrodes (anodes) to the cathodes under the effect of the EO and EM forces. Electrode selection is important, since many metal or carbon anodes rapidly dissolve after contact with strong oxidants.



Electrokinetic Remediation Process

WASTE APPLICABILITY:

Electrokinetic soil processing extracts heavy metals, radionuclides, and other inorganic contaminants below their solubility limits. During bench-scale testing, the technology has removed arsenic, benzene, cadmium, chromium, copper, ethylbenzene, lead, nickel, phenol, trichloroethylene, toluene, xylene, and zinc from soils. Bench-scale studies under the SITE Program demonstrated the feasibility of removing uranium and thorium from kaolinite.

Limited pilot-scale field tests resulted in lead and copper removal from clays and saturated and unsaturated sandy clay deposits. Treatment efficiency depended on the specific chemicals, their concentrations, and the buffering capacity of the soil. The technique proved 85 to 95 percent efficient when removing phenol at concentrations of 500 parts per million (ppm). In addition, removal efficiencies for lead, chromium, cadmium, and uranium at levels up to 2,000 micrograms per gram ranged between 75 and 95 percent.

STATUS:

Based on results from the Emerging Technology Program, the electrokinetic technology was invited in 1994 to participate in the SITE Demonstration Program. For further information on the pilot-scale system, refer to the Emerging Technology Bulletin (EPA/540/F-95/504), which is available from EPA.

The SITE demonstration began in July 1995 at an inactive firing range at the Fort Polk Army Ammunition Reservation in Louisiana. The soil at the site is contaminated with lead, copper, and zinc, which have accumulated over several decades. Concentrations of lead in the sandy clay soil range from 1,000 to 5,000 ppm and are less than 100 ppm at a 3-foot depth. A 20-foot by 60-foot area will be remediated to a depth of 3 feet. Remediation of the site is expected to be completed within 9 to 12 months of processing. This demonstration represents the first comprehensive study in the United States of an in situ electrokinetic separation technology applied to heavy metals in soils.

FOR FURTHER INFORMATION:

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TECHNOLOGY DESCRIPTION:

rendering them unleachable by the toxicity characteristic leaching procedure (TCLP).

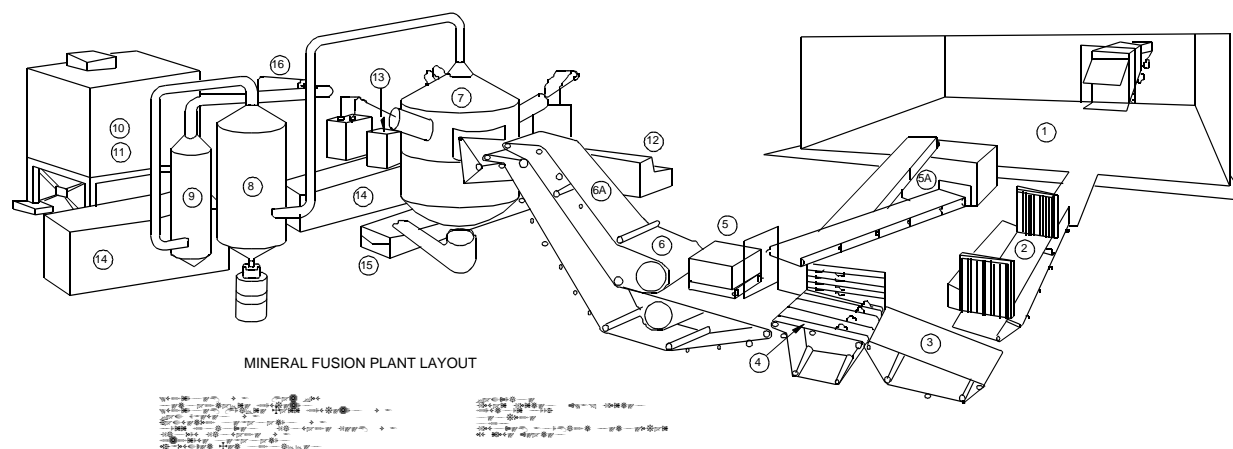
STATUS:

This technology was accepted into the SITE Program in December 1994. The SITE demonstration will occur during the second phase of a two-phase New Jersey Department of Environmental Protection-funded research project that is being coordinated by the New Jersey Institute of Technology, Hazardous Substance Management Research Center.

WASTE APPLICABILITY:

This technology has been successfully used to process municipal solid waste incinerator ash, fly ash or bottom ash, asbestos-containing materials, and various slag materials. The developer claims that the technology can also be used to incorporate heavy metals, such as cadmium or chromium,

A bench-scale study in 1994 established the performance of the process based on leachability of chromium and the concentration of free hexavalent chromium in the glass product. The study included the collection and subsequent analysis of soils from nine chromium-contaminated sites in northern New Jersey. The soils were analyzed for total chromium and total hexavalent chromium; the soils also underwent TCLP analyses for chromium. The concentrations of hexavalent chromium were as high as 4,800 milligrams per kilogram in untreated soil. The results of the evaluation indicated that



Schematic Diagram of the Cold-Top Ex Situ Vitrification of Chromium-Contaminated Soils

concentrations of chromium in the leachate from TCLP analyses were generally less than 1 milligram per liter (mg/L), and that the concentrations of chromium in all samples were below the regulatory threshold concentration of 5 mg/L.

During the SITE demonstration, 3-ton samples from the Colony Diner site and the Liberty State Park site in Jersey City, New Jersey will be vitrified. Cold-Top ex situ vitrification will attempt to render hexavalent chromium unleachable, and destroy other trace organics found in soil from the New Jersey sites. In addition, the vitrified product will be tested for potential reuse in road construction. The SITE demonstration is expected to occur in 1997.

FOR FURTHER INFORMATION:

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LASAGNA™ PUBLIC-PRIVATE PARTNERSHIP (Lasagna™ In Situ Soil Remediation)

TECHNOLOGY DESCRIPTION:

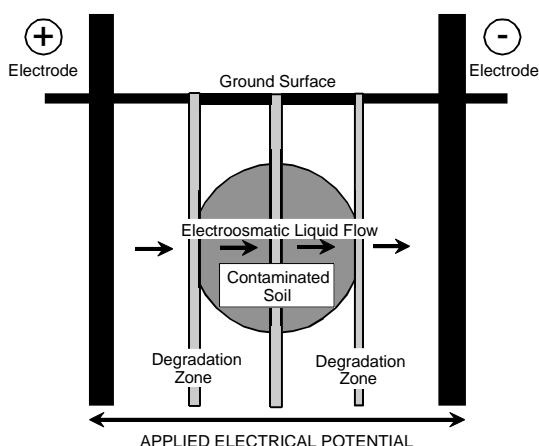
The Lasagna™ process, so named because of its treatment layers, combines electroosmosis with treatment layers which are installed directly into the contaminated soil to form an integrated, in situ remedial process. The layers may be configured vertically (Figure 1) or horizontally (Figure 2). The process is designed to treat soil and groundwater contaminants completely in situ, without the use of injection or extraction wells.

The outer layers consist of either positively or negatively charged electrodes. An electric field is created by the electrodes, and the electric field created by the electrodes moves contaminants in soil pore fluids into or through the treatment layers. In the vertical configuration, steel rods, may be used as electrodes. In the horizontal configuration, the electrodes and treatment zones are installed by hydraulic fracturing. Granular graphite is used for the electrodes and the treatment zones are granular iron (for zero-valent, metal-enhanced, reductive dechlorination) or granular activated carbon (for biodegradation by methanotrophic microorganisms).

The Lasagna™ process can remove contaminants from soil in three ways:

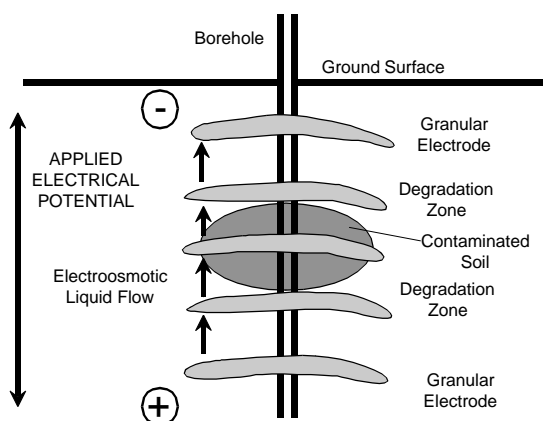
- Creating treatment zones in close proximity to one another throughout the contaminated soil region, and converting them into sorption/degradation zones by introducing sorbents, catalytic agents, microbes, oxidants, or buffers
- Using electrokinetics to transport contaminants from the soil into the treatment zones for degradation
- Reversing the direction of transport, if necessary, switching electrical polarity

The orientation of the electrodes and treatment zones depends on the characteristics of the site and the contaminants. In general, the vertical configuration is probably applicable to more shallow contamination, within 50 feet of the ground surface. The horizontal configuration, using hydraulic fracturing or related methods, is uniquely capable of treating much deeper contamination.



Note: Electroosmotic flow is reversed upon switching electrical polarity.

Vertical Configuration
of the Lasagna™ Process



Note: Electroosmotic flow is reversed upon switching electrical polarity.

Horizontal Configuration
of the Lasagna™ Process

WASTE APPLICABILITY:

Conceptually, the Lasagna™ process is designed to treat organic and inorganic contaminants and mixed wastes in groundwater and soil. To date, the process has been tested primarily on organic contaminants in low permeability soils.

STATUS:

The Lasagna™ process (vertical configuration) was accepted into the SITE Demonstration Program in 1995. The horizontal configuration is not being evaluated by the SITE Demonstration Program because the work is being conducted by EPA employees in conjunction with the University of Cincinnati. EPA is conducting work on the horizontal configuration under a cooperative research and development agreement with a private research consortium consisting of Monsanto, DuPont, and General Electric. This collaborative effort between the federal government and industry is a result of an action team of the Remediation Technologies Development Forum (RTDF). The RTDF identifies ways that the federal government can work with private industry to solve complex contamination problems at hazardous waste sites.

Under the SITE Program, with significant funding from the U.S. Department of Energy (DOE), the Lasagna™ process was tested for 120 days in May 1995 on soil contaminated with trichloroethene (TCE) at DOE's Paducah Gaseous Diffusion Plant (PGDP) in Kentucky. One of the key objectives of this test was to successfully demonstrate the coupling of electroosmotic flushing of TCE from the clay soil while removing the TCE from the pore water by in situ adsorption. Steel panels were used as electrodes and granular activated carbon served as treatment layers in a vertical configuration.

Sampling and analysis of the carbon at the end of the test revealed a substantial amount of TCE. Soil samples collected before and after the test indicated a 98 percent removal of TCE from tight clay soil, with some samples showing greater than 99 percent removal. TCE soil levels were reduced from the 100 parts per million (ppm) range to an average concentration of 1 ppm.

A second test of the Lasagna™ process in a vertical configuration is underway on larger volumes of soil at DOE's PGDP under the Rapid Commercialization Initiative (RCI). RCI was created by the Department of Commerce, Department of Defense, Department of Energy, and EPA to assist in the integration of innovative technologies into the marketplace.

EPA and the University of Cincinnati have installed horizontal configuration cells at Rickenbacker Air National Guard Base (ANGB) near Columbus, OH. Support facilities are being installed at Offutt Air Force Base (AFB) near Omaha, NE. Horizontal configuration cells will be installed at Offutt AFB in spring 1997 with funding support from the U.S. Air Force. TCE is the target contaminant at both Rickenbacker ANGB and Offutt AFB.

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LOCKHEED MARTIN MISSILES AND SPACE CO. and GEOKINETICS INTERNATIONAL, INC.

(Electrokinetic Remediation Process)

TECHNOLOGY DESCRIPTION:

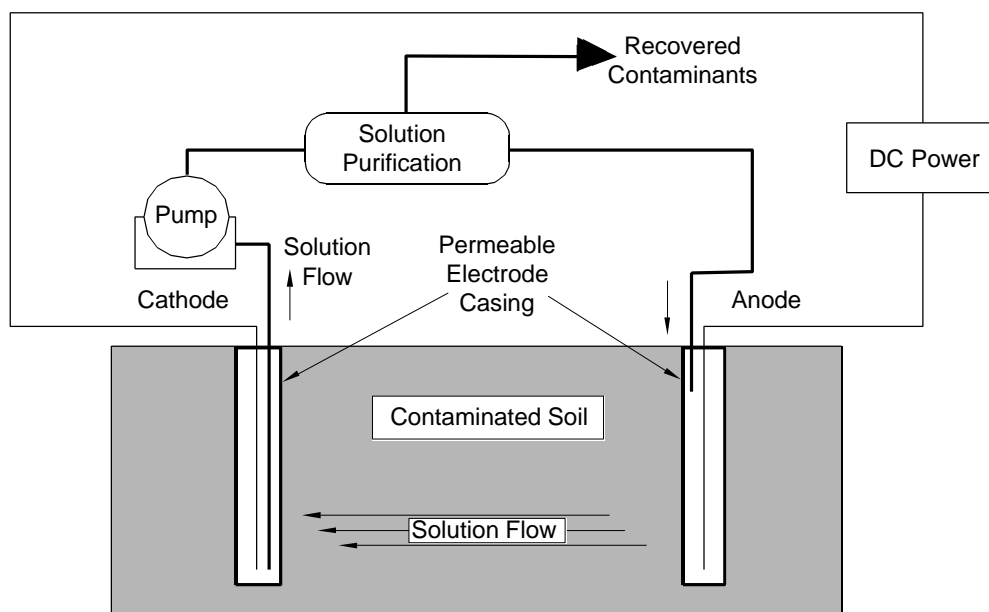
The Electrokinetic Remediation (ER) process removes metals and organic contaminants from soil, mud, sludge, and marine dredgings. ER uses electrochemical and electrokinetic processes to desorb and remove metals and polar organics. The technology may be applied in situ or in the batch mode.

The figure below is a flow diagram of the batch reactor. Waste material is placed into the batch reactor, between Ebonex® ceramic electrodes that are divided into a cathode array and an anode array. A direct current is then applied, causing ions and water to move toward the electrodes. Metal ions, ammonium ions, and positively charged organic compounds move toward the cathode. Anions such as chloride, cyanide, fluoride, nitrate, and negatively charged organic compounds move toward the anode. Two primary mechanisms transport contaminants through the soil: electromigration and electroosmosis. In electromigration, charged particles are transported through the substrate. In

contrast, electroosmosis is the movement of a liquid containing ions relative to a stationary charged surface. Of the two, electromigration is much faster and it is the principle mechanism for the ER process.

The electrodes are positioned inside permeable casings that are inserted into the waste material. After the annulus of each casing is filled with water, the current is turned on. The water passes from the anode casing into the waste and toward the cathode. This procedure (1) supports electrokinetic movement of the contaminants through the soil; (2) helps maintain soil moisture, thereby sustaining the electric field; and (3) enables various chemicals that enhance contaminant removal to be added as required.

As the water accumulates in the annulus of the cathode casing, it is pumped out for processing. Processing involves removal of contaminants by electrochemical means, producing a concentrated contaminant brine that can be either further processed or disposed of as hazardous waste. The



Flow Diagram of the Electrokinetic Remediation Process

water is then returned to the annulus of the anode casing.

WASTE APPLICABILITY:

ER is designed to remove heavy metals, anions, and polar organics from soil, mud, sludge, and dredgings. Treatable concentrations range from a few parts per million (ppm) to tens of thousands ppm. The batch technology is most appropriate for sites with contaminated estuarine and river muds and dredgings, sewage processing sludges, and fines remaining after soil washing. The process can be used with virtually any substrate. ER's effectiveness is sharply reduced for wastes with a moisture content of less than 10 percent.

STATUS:

This technology was accepted into the SITE Demonstration Program in 1994. A demonstration of the process will be conducted at the Alameda Naval Air Station in California.

The ER process has been used successfully at several European sites (see table below) on soils contaminated with metals.

FOR FURTHER INFORMATION:

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Site Description	Site Dimensions (in meters [m])	Contaminants	Initial Concentration	Final Concentration
Former paint factory (limited duration field trial)	70 m x 3 m	Copper Lead	> 5,000 ppm 500-1,000 ppm	1,000 ppm 150-300 ppm
Galvanizing plant (limited duration field trial)	15 m x 6 m	Zinc	2,400 ppm average	1,680 ppm average
Former timer impregnation plant	25 m x 15 m	Arsenic	115 ppm average	10 ppm average
Temporary landfill	70 m x 40 m	Cadmium	250 ppm average	< 20 ppm
Soil deposit on military airbase	90 m x 20 m	Cadmium Chromium Copper Lead Nickel Zinc	2,600 ppm 770 ppm 730 ppm 660 ppm 7,300 ppm 860 ppm	150 ppm 10-20 ppm 10-20 ppm 10-20 ppm 10-20 ppm 10-20 ppm

Performance Summary of In Situ Electrokinetic Remediation Process
Applied at Five Field Sites in Europe